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Utilization and Cost of Mammography Screening Among Commercially Insured Women Aged 50 to 64 Years in the United States, 2012-2016

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Abstract

Background: In recent years, most insurance plans eliminated cost-sharing for breast cancer screening, recommended screening intervals changed, and newer modalities—digital mammography and breast tomosynthesis—became more widely available. The objectives of this study are to examine how these changes affected utilization, frequency, and costs of breast cancer screening among commercially insured women, and to understand factors associated with utilization and frequency of screening.

Methods: This study used commercial insurance claims data for women aged 50 to 64 years continuously enrolled in commercial insurance plans during 2012–2016.

Results: Of the 685,737 eligible women, 20% were not screened, 40% received annual screening, 24% received biennial screening, and 16% were screened less frequently than recommended during the time period examined. Sociodemographic factors such as age <60 years, rurality, and fee-for-service insurance were associated with low screening utilization. Patients who received annual screening incurred approximately 1.78 times higher costs as compared to those who received biennial screening during the study period. Digital mammography was the most costly and commonly used modality along with computer-aided detection.

Conclusions: Evidence-based interventions to promote screening among women who are screened less frequently are needed along with interventions to move toward biennial screening rather than annual screening. Increasing provider awareness regarding breast cancer screening

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rates and frequency among various sociodemographic groups is essential to guide provider recommendations and shared decision making. The results of this study can guide targeted public health interventions to reduce barriers to screening, and can also serve as inputs for economic analyses of screening interventions and programs.

Keywords

mammography; breast cancer; cost; utilization; digital breast tomosynthesis

Introduction

Breast cancer screening with mammography is recommended to reduce breast cancer mortality for women aged 50–74 years.[1] Beginning in 2011, many private health insurers were required to cover mammography screening without cost-sharing.[2] Little evidence exists about how these changes affected screening utilization among commercially insured women.[3,4] Analysis of the 2015 National Health Interview Survey (NHIS) indicated that 76.7% of privately insured women aged 50–74 received a mammogram within the past 2 years.[5] Although cancer screening prevalence is commonly based on self-reported data such as the NHIS, these estimates may be overreported.[6] The evidence is scant on the sociodemographic factors associated with breast cancer screening utilization and frequency among commercially insured women, after elimination of financial barriers.

Consistent with its 2009 recommendation for women aged 50–74 years, in the 2016 update, the US Preventive Services Task Force (USPSTF) reaffirmed its position that women in this age group who have an average risk of developing breast cancer should undergo routine biennial screening mammography.[7] However, there were different guidelines from other medical organizations such as the American Cancer Society (updated to biennial screening for women aged 55 years and above in October, 2015[8]) and the American College of Radiology (annual screening for women aged 50 to 64 years).[9,10] Compared to biennial screening, annual screening has additional costs and may not provide the best balance of harms and benefits for many women.[7] Previous research among commercially insured women has not examined the rate of annual screening and its associated factors and the additional cost of annual screening compared to biennial screening.

Since early 2000, digital mammography with or without computer-aided detection (CAD) has become the most commonly used breast cancer screening modality in the US.[11] While film mammography had been the mainstay prior to 2000, today nearly 90% of all mammography screenings in the United States are digital.[12] Digital mammography costs more,[13,14] may offer no significant advantage in older women without dense breasts,[15] and may not be cost-effective in women aged 50 years and older.[16] The utilization of CAD and digital breast tomo-synthesis (DBT) is rising because it can decrease recall rates among women<50 years with dense breasts.[17] However, the benefits of these new, high-cost modalities for screening women aged 50 to 64 years without dense breasts are uncertain[7,18,19] and the evidence regarding their cost-effectiveness is limited due to lack of precise cost estimates.[20,21] An understanding of the utilization and costs of various breast cancer screening modalities can inform efforts to identify screening strategies that provide

the best value. Previous research has not examined the proportion of privately insured women who still pay some out-of-pocket (OOP) costs for each screening modality and the mean OOP costs paid by these women using claims data.

This study of breast cancer screening among commercially insured women aged 50 to 64 years during 2012–2016 has four objectives: 1) to examine the utilization and frequency of mammography after elimination of cost-sharing in many private insurance plans, 2) to examine sociodemographic factors associated with utilization and frequency, 3) to estimate the utilization, direct medical costs, and OOP costs of various screening modalities by type of insurance plan, and 4) to estimate aggregate costs by screening frequency and the cost-savings associated with biennial screening compared to annual screening.

Materials and Methods

Data source

Outpatient claims data from January 1, 2011 to December 31, 2016 were used for this study, from the IBM Watson Health MarketScan Treatment Pathways® 100% data file, derived from the Truven Health MarketScan Commercial Claims and Encounters database. The MarketScan Commercial Claims and Encounters database contains person-level enrollment information linked to fully paid and adjudicated outpatient medical care claims for nearly 43.6 million individuals annually who are covered by employer-sponsored group insurance.[22]

Population Selection

The study population included all women with an outpatient claim continuously enrolled from January 1, 2011 to December 31, 2016 aged 50 to 64 years. Data from 2011 were used as a ‘look back’ period to exclude women with a diagnosis of breast cancer, breast involvement due to any disease condition, breast signs or symptoms such as lump, pain, breast inversion, or nipple discharge and lastly, women with a mastectomy. The look back period in this study is defined as the period between January 1, 2011 and the index date. The index date for those women who got a screening mammography is the date of the first screening whereas for those who did not get screened from 2012–2016, the index date is December 31, 2016. Diagnosis and procedure codes for screening modalities and exclusion criteria are presented in the Appendix. Since ICD-10 codes were adopted in October 2015, both ICD-9 and ICD-10 diagnosis codes were used for identifying exclusion criteria.[23] Women with capitated insurance plans and missing insurance plan information were excluded since the utilization and cost estimates for capitated plans are not accurately captured in MarketScan data. This study used de-identified patient records and did not involve the collection, use, or transmittal of individually identifiable data, therefore, Institutional Review Board approval was not required.

Data Analysis

This study was a retrospective observational cohort analysis utilizing the MarketScan Treatment Pathways (Truven Health Analytics, Inc., Ann Arbor, MI), a web-based data analysis tool. The tool was used to estimate the breast cancer screening utilization,

frequency and costs. In this study, annual screening was defined as average screening interval <1.5 years. Biennial screening was defined as average screening interval ≥1.5 years, and ≤2.5 years. Infrequent screening was defined as average screening interval greater than 2.5 years.

The association between sociodemographic factors and utilization and frequency of breast cancer screening was first examined using bivariate analysis. The variables significant in the bivariate analyses were included in a multivariate logistic regression to estimate the odds ratios for receiving at least one screening mammogram during 2012–2016. Next, the relationship between demographic factors and screening frequency was examined using multinomial logistic regression. Screening frequency was categorized as 1) annual screening, 2) biennial screening, 3) infrequent screening (screening interval greater than 2.5 years) and 4) no screening. No screening was used as the referent group for the multinomial regression.

The sociodemographic factors included in the analyses were age, geographic region, residence in a metropolitan statistical area as defined by U.S. Office of Management and Budget,[24] relationship to insured employee (self or spouse), and type of insurance plan. Age was categorized as women aged 50–54, 55–59, and 60–64 years. Health insurance plans were categorized as 1) fee-for-service (FFS) including comprehensive plans, 2) non-capitated managed care plans including exclusive provider organization, non-capitated point of service and preferred provider organization plans, and 3) high deductible plans including consumer directed health plans (CDHP) and high-deductible health plans (HDHP).

The direct medical cost and OOP cost for each screening modality by type of insurance were estimated by aggregating claims for the same procedure on the same service date for each enrollee. The direct medical cost of a procedure represents the amount eligible for payment after applying pricing guidelines such as fee schedules and discounts, and including deductibles, copayments, and coordination of benefits. The OOP cost was calculated by summing the copayment, coinsurance, and deductible paid by the patient. The mean OOP costs are computed only for those women who had a non-zero OOP cost. The costs reported are point-of-care costs. Costs related to harm of breast cancer screening were not captured in the analysis.

Total cost of all screening modalities per person was obtained by adding costs for all screening modalities received by a woman during the study period. Total costs by screening frequency were computed as a product of the number of women receiving annual, biennial, or infrequent screening and total cost of all screening modalities per person. Total costs for the entire sample were computed as a product of the number of women receiving any screening during the study period and total cost of all screening modalities per person. Costs for each year were converted to 2017$ using the Personal Health Care Expenditure (PHCE) component of the National Health Expenditure Accounts from Centers for Medicare and Medicaid Services (CMS).[25] Next, the weighted average of costs for all years in 2017$ was computed based on utilization by year. All statistical analyses were performed using Stata 14.

Results

The sample flow diagram along with the inclusion and exclusion criteria is presented in Figure 1. The total number of women who met the study selection criteria was 685,737.

Breast cancer screening utilization and frequency

Table 1 presents the sample characteristics. Table 2 presents sample characteristics by receipt of any screening and by frequency of screening. Sample characteristics are presented as row percentages i.e. the percentages in the rows add up to 100%. Table 2 also presents results of bivariate analysis wherein women receiving at least one screening were compared to women who received no screening and women receiving annual, biennial, infrequent and no screening were compared to each other. Of all the women eligible to receive breast cancer screening, 80.3% (550,533) had at least one screening mammogram in 2012–2016 whereas 19.7% (135,204) received no screening. Women aged 50–54 years and 55–59 years, spouses of employees, residing in northeast region, in non-metropolitan areas, and enrolled in fee-for-service plans less often received any screening mammogram during the study period compared to women aged 60–64 years residing in metropolitan areas in regions other than northeast and enrolled in commercial insurance plans other than fee-for-service, respectively.

There were 166,579 (24.3% of all eligible women) who were screened biennially; 273,949 (40.0%) who were screened annually, and 110,005 (16.0%) who were screened at intervals greater than 2.5 years. Annual screening was more common among women aged 50 to 54 and 55 to 59 compared to older women whereas infrequent screening was more common among women aged 60 to 64 years. Annual screening was more common among women enrolled in a consumer directed/high deductible health plan whereas infrequent screening and no screening was more common among women enrolled in fee-for-serve plans. Annual screening was more common among women residing in the South and biennial screening among women residing in the West. Differences in infrequent screening across regions were small. Annual screening was more common among employees whereas infrequent screening was more common among spouses of employees. All variables were significant in the bivariate analyses at P-value<0.01.

Factors associated with breast cancer screening utilization and frequency

Table 3 presents the odds ratios (OR) and 95% confidence intervals (CIs) from the logistic regression with receipt of at least one breast cancer screening during the study period as the dependent variable. Women aged 50–54 years (OR: 0.33, 95% CI: 0.32–0.34) and 55–59 years (OR: 0.4 95% CI: 0.39–0.41) (comparison group: 60–64 years), residing in non-metropolitan areas (OR: 1.3, 95% CI: 1.28–1.32) (comparison group: metropolitan areas), residing in the Northeast (OR: 0.59, 95% CI: 0.58–0.6) and Midwest region (OR: 0.88, 95% CI: 0.86–0.89) (comparison group: South), women enrolled in a fee-for-service plan, and spouses of insured employees (OR: 0.87, 95% CI: 0.86–0.88) (comparison group: employee) were significantly less likely to receive any breast cancer screening during the study period. Conversely, women enrolled in a non-capitated managed care plan (OR: 1.98, 95% CI: 1.94–2.03) or high deductible plan (OR: 2.68, 95% CI: 2.6–2.76) (comparison group: fee-for-

service) were significantly more likely to receive any breast cancer screening during the study period.

Table 3 also reports relative risk ratios (RR) from the multinomial logistic regression with screening frequency (annual screening, biennial screening, infrequent screening or no screening) as the dependent variable and no screening as the referent group. Relative to those who received no screening, women aged 50–54 years (RR: 0.33, 95% CI: 0.32–0.34) and 55–59 years (RR: 0.40, 95% CI: 0.39–0.41), spouses of insured employees (RR: 0.87, 95% CI: 0.86–0.88), those residing in the Northeast (RR: 0.50, 95% CI: 0.50–0.51), West (RR: 0.89, 95% CI: 0.87–0.91) or Midwest (RR: 0.94, 95% CI: 0.92–0.95) region, and enrolled in fee-for-service plans were significantly less likely to receive annual screening.

Relative to those who received no screening, women aged 50–54 years (RR for biennial screening: 0.39, 95% CI: 0.38–0.40) (RR for infrequent screening: 0.12, 95% CI: 0.12–0.12) and 55–59 years (RR for biennial screening: 0.44, 95% CI: 0.43–0.45) (RR for infrequent screening: 0.21, 95% CI: 0.20–0.22), spouses of insured employees (RR for biennial screening: 0.91, 95% CI: 0.89–0.92) (RR for infrequent screening: Not statistically significant), those residing in the Northeast (RR: 0.54, 95% CI: 0.53–0.55) (RR for infrequent screening: 0.61, 95% CI: 0.60–0.63), or Midwest (RR for biennial screening: 0.97, 95% CI: 0.95–0.99) (RR for infrequent screening: 0.97, 95% CI: 0.95–0.99) region, and enrolled in fee-for-service plans were significantly less likely to receive biennial screening and infrequent screening.

Utilization and cost of breast cancer screening modalities by type of insurance

The utilization and costs (direct medical and OOP) of screening modalities along with proportion of women with non-zero OOP costs by type of insurance plan are presented in Table 4. Utilization is defined as the percentage of women who received the screening modality at least once during the study period. Among women who received at least one screening mammogram between 2012 and 2016, 97.6% received digital, 19.7% received film, 96.3% received CAD and 14.0% received digital breast tomosynthesis (DBT) (Table 4). Utilization of screening modalities varied by type of insurance plan. Compared to other types of insurance plans, fee-for-service plans had the lowest utilization for DBT and the highest utilization for film mammogram whereas high deductible plans had the highest utilization of DBT. There was little difference in utilization of digital mammography and CAD across groups.

Direct medical costs were $112.75 (95% CI: 111.97–113.54) for film mammography, $175.58 (95% CI: 175.18–175.97) for digital mammography, $28.42 (95% CI: 28.27–28.57) for CAD, and $31.83 (95% CI: 31.29–32.37) for DBT. The direct medical costs for screening modalities varied by type of insurance plan. Women enrolled in high deductible plans had the lowest mean direct medical costs for film and digital mammography and those enrolled in fee-for-service plans had the lowest mean costs for CAD and DBT.

Only 5.2% of the women receiving breast cancer screening had OOP costs. The presence of OOP costs varied by screening modality, 3.0% of those who received CAD, 3.2% of those who received film mammography, 3.5% of those who received digital mammography, and

7.8% of those who received DBT had any OOP costs. The mean OOP cost for women who had non-zero OOP costs was $48.76 (95% CI: 45.01–52.41) for film, $62.66 (95% CI: 61.01–64.31) for digital, $10.79 (95% CI: 10.10–11.48) for CAD, and $40.52 (95% CI: 38.79–42.24) for DBT. The mean OOP costs varied by type of insurance plan. Women enrolled in high deductible plans had the highest mean OOP costs for all screening modalities except film mammography. Those enrolled in non-capitated managed care plans had the lowest mean OOP costs for film and digital mammography whereas OOP costs for CAD and DBT were lowest among those enrolled in fee-for-service plans.

Additional costs for women who received annual screening in 2012–2016

Table 5 presents the mean total cost per person for screening and the mean total cost for the sample by screening frequency. Women who received annual screening had a mean total cost of $1411.23 (95% CI: 1407.35–1415.1) whereas women who received biennial screening had a mean total cost of $792.10 (95% CI: 789.13–795.07). Thus, women who received annual screening incurred approximately 1.78 times higher costs or an additional $619.13 (95% CI: 618.22–620.33) as compared to those who received biennial screening during the study period. A total of 273,949 women who received annual screening during the study period had a total cost of $39 million whereas 166,579 women who received biennial screening during the study period had a total cost of $13 million.

Discussion

Summary of results

Among commercially insured women aged 50–64 years in 2012–2016, 64% received breast cancer screening with screening interval less than≤2.5 years. This is lower than the Healthy People 2020 biennial screening target of 81%.[26] Despite elimination of financial barriers in many private plans, 20% eligible women still did not receive any screening during the study period and 16% received infrequent screening. Women aged 50 to 59 years, residing in non-metropolitan areas, in the Northeast and Midwest regions, enrolled in fee-for-service plans, and spouses of insured employees were less likely to receive at least one breast cancer screening during the study period. While women aged 60 to 64 years had higher likelihood of receiving at least one screening mammogram, they were more likely to have longer than recommended interval between mammograms. Out of the women who received at least one screening mammogram during 2012–2016, 50% received annual screening. Compared to women who received no screening, women aged 60–64 years, insured employees, residing in the South, and enrolled in non-capitated managed care or high deductible health plans had higher rates of receiving annual screening. If annual screening was substituted by biennial screening in the study sample, it would result in per-person saving of $619 in direct medical costs.

Some evidence suggests that newer diagnostic modalities have uncertain benefits women aged 50 to 64 years. Prior studies have reported that for some women there may be no statistically significant differences in sensitivity and specificity of film mammography and the more costly digital mammography.[13,15] Cole et al. (2014) reported that sensitivity and specificity of CAD is not significantly different from digital mammography.[27] Lei et al.

(2014) reported that DBT has higher sensitivity (90% vs 89%) and specificity (79% vs 72%) than digital mammography based on a meta-analysis of seven studies.[28] However, the value of CAD and DBT is uncertain in older women (>50 years of age) who do not have dense breasts.[19] Despite uncertain benefits, the results of this study suggest high utilization of digital mammography (98%) and CAD (96%) in this sample of women aged 50–64 years. DBT utilization in this sample was 14%. The costs for mammography among commercially insured women in this study were higher than the amount allowed by Medicare in 2015 for all modalities except DBT. This included the commercial costs for film mammography ($113 in 2017$ for commercial vs. $83 Medicare), digital mammography ($176 in 2017$ commercial vs. $135 Medicare), and CAD ($28 in 2017$ for commercial vs. $9 for Medicare). The commercial costs for DBT ($32 in 2017$ for commercial vs. $56 for Medicare) were lower than the amount allowed by Medicare.[29]

Only 5% of women had any OOP costs, 3% of those receiving film mammography and CAD, 4% of those receiving digital mammography, and 8% of those receiving DBT had OOP costs. This could be due to the novelty of DBT as a screening modality. Since 2011, patient cost-sharing for breast cancer screening was eliminated in many private plans. Results from this study suggest that during 2012–2016 the vast majority of women had no OOP cost for mammography.

Implications

Despite elimination of financial barriers in many plans, only 64% of commercially insured women received breast cancer screening biennially or more often. This finding underscores the importance of understanding and addressing non-financial barriers to screening. Evidence-based interventions recommended by the Community Preventive Services Task Force (CPSTF) can be implemented to increase screening use by increasing community demand for cancer screening, increasing provider delivery of screening services and reducing structural barriers to care.[30] Some of these interventions include patient reminders which have been implemented to increase screening rates among insured populations.[30] CPSTF also provides recommendations for interventions to reduce structural barriers such as lack of transportation or inability to take time off work, and cultural and language barriers that can impede breast cancer screening, even among insured women.[31] For those who still encounter cost barriers, reducing OOP costs is also recommended by the CPSTF to increase screening mammography use.[32] Our study showed that women who were aged 50 to 59 years, residing in non-metropolitan areas, spouses of employees, and enrolled in fee-for-service plans may benefit from targeted interventions recommended by CPSTF. A recent report highlighted that despite similar incidence of breast cancer, rural areas experienced higher cancer deaths.[33] Eliminating urban-rural disparities in screening may help reduce breast cancer deaths in non-metropolitan rural areas. CPSTF recommends several interventions to reduce structural barriers including offering services in alternative or non-clinical settings such as mobile mammography vans in residential communities, eliminating or simplifying administrative procedures and providing services such as scheduling assistance, patient navigators, translation services, and transportation assistance.[27] These interventions may help reduce rural disparities in utilization of breast cancer screening.

Although breast cancer screening is known to reduce breast cancer mortality among women aged 50 to 64 years, there are certain harms associated with screening. These include false-positive rates resulting in anxiety and distress, overdiagnoses associated with increased biopsies and other procedures, and pain and radiation exposure during the screening.[34] Nelson et al. reported that false-positive rates (61% vs 42%) and biopsies (7% vs 5%) were more common with annual screening than biennial screening.[34] Thus, annual screening has higher costs and may not provide the best balance of benefits and harms compared to biennial screening.[7,35] Among women who received at least one screening during the study period, 50% received annual screening. This finding indicates that despite USPSTF recommendations, annual screening continues as a routine practice. Barriers to adoption of USPSTF biennial screening recommendations by physicians may include patient preferences, concern about malpractice risk, preference for guidelines from American Cancer Society or other organizations, health system assessment of provider's screening practices that use conflicting measurement criteria, and lack of time or training for shared decision making with patients.[36] These barriers can be addressed by patient and physician education, use of decision tools for shared decision making, and better patient-physician communication in order to use limited healthcare resources in a way that provides the best value.[37,38]

The costs of mammography screening to the society are sensitive to the costs of screening modalities and the screening strategies used (biennial vs annual).[35,39] Thus, it is important to understand the cost of each screening modality and the additional cost of annual screening as compared to biennial. Given the increased cost of newer modalities such as digital mammogram, CAD and DBT, understanding which women may benefit from them is important. In addition to the financial costs of screening modalities, understanding the harms of screening associated with newer modalities is also important. While combining tomosynthesis with mammography resulted in a decrease in recalls, it also resulted in an increase in biopsies compared with mammography alone.[34]

The results from this study highlight sub-populations that may benefit from evidence-based interventions to increase screening. These results also highlight the importance of physician awareness regarding screening rates and frequency among various sub-populations to guide shared decision making for screening. Lastly, the costs of screening modalities presented in this study can serve as inputs for future research on economic analyses of various alternative screening strategies, and interventions and programs to improve screening uptake.

Limitations

This study has some limitations. First, participating plans included in MarketScan may change over time, and as a result, conclusions about patterns of care, geographic differences, and changes over time may not be representative of the entire United States.[40] Second, study outcomes were identified through administrative claims data, which are subject to data coding limitations and data entry errors. Third, the study was not designed to identify women for whom more frequent screening may be indicated (e.g. women at high risk for breast cancer including women with a family history of cancer, women recommended to have short interval follow up during the study period) or for whom newer modalities may be

appropriate (e.g. women with dense breasts). Fourth, the look-back period in this study to identify women who may have received a diagnostic screen is only one year since including extra years of look-back period may require increasing the number of years for which women need to be continuously enrolled. The shorter look-back period in this study may overestimate the prevalence of preventive screens. Fifth, this study did not control for comorbidities. Sixth, due to lack of data, racial and ethnic disparities in screening could not be analyzed. Lastly, the study is restricted to women aged 50 to 64 years so the results are not generalizable to younger women under 50 years of age.

Conclusions

In conclusion, this study provides valuable data on utilization, frequency, and cost of various breast cancer screening modalities among commercially insured women aged 50–64 years from 2012 to 2016. The results point to populations with lower likelihood of screening that may benefit from evidence-based interventions. The results of this study also draw attention to prevalence and additional costs of annual screening among women aged 50 to 64 years. Provider awareness of screening utilization and frequency among various sub-groups can guide appropriate provider recommendations and shared decision-making. The cost results presented in this study may serve as inputs for economic analyses of alternate screening strategies, programs, and interventions to improve screening uptake. The results of this study can guide targeted public health interventions such as small media, patient and provider reminders, and interventions to eliminate structural barriers[27] in order to improve breast cancer screening rates.

Appendix

APPENDIX 1:

Diagnosis and Procedure Codes for Breast Cancer Screening and Breast Involvement

Description	Code Type	Code
Codes to identify breast cancer screening		
Screening mammography, bilateral (2-view film study of each breast)	CPT Procedure	77057
Screening mammography, producing direct digital image, bilateral, all views	HCPS	G0202
Add on code for computer-aided detection (computer algorithm analysis of digital image data for lesion detection) with further review for interpretation, with or without digitization of film radiographic images; screening mammography	CPT Procedure	77052
Add on code for screening digital breast tomosynthesis, bilateral	CPT Procedure	77063
Codes to identify breast cancer diagnosis		
Malignant neoplasm of nipple and areola of female breast	ICD-9 Diagnosis	174.0
	ICD-10 Diagnosis	C50.01x
Malignant neoplasm of central portion of female breast	ICD-9 Diagnosis	174.1
	ICD-10 Diagnosis	C50.11x
Malignant neoplasm of upper-inner quadrant of female breast	ICD-9 Diagnosis	174.2
	ICD-10 Diagnosis	C50.21x
Malignant neoplasm of lower-inner quadrant of female breast	ICD-9 Diagnosis	174.3

Description	Code Type	Code
	ICD-10 Diagnosis	C50.31x
Malignant neoplasm of upper-outer quadrant of female breast	ICD-9 Diagnosis	174.4
	ICD-10 Diagnosis	C50.41x
Malignant neoplasm of lower-outer quadrant of female breast	ICD-9 Diagnosis	174.5
	ICD-10 Diagnosis	C50.51x
Malignant neoplasm of axillary tail of female breast	ICD-9 Diagnosis	174.6
	ICD-10 Diagnosis	C50.61x
Malignant neoplasm of other specified sites of female breast	ICD-9 Diagnosis	174.8
	ICD-10 Diagnosis	C50.81x
Malignant neoplasm of breast (female) unspecified site	ICD-9 Diagnosis	174.9
	ICD-10 Diagnosis	C50.91x
Secondary malignant neoplasm of skin of breast	ICD-9 Diagnosis	198.2x
	ICD-10 Diagnosis	C79.2x
Secondary malignant neoplasm of breast	ICD-9 Diagnosis	198.81
	ICD-10 Diagnosis	C79.81
Carcinoma in situ of breast	ICD-9 Diagnosis	233.0
	ICD-10 Diagnosis	D05.xx
Neoplasm of uncertain behavior of breast	ICD-9 Diagnosis	238.3
	ICD-10 Diagnosis	D48.6x
Neoplasm of unspecified nature of breast	ICD-9 Diagnosis	239.3
	ICD-10 Diagnosis	D49.3
Personal history of malignant neoplasm of breast	ICD-9 Diagnosis	V10.3
	ICD-10 Diagnosis	Z85.3
Codes to identify breast cancer sign or symptom		
Lump or mass in breast	ICD-9 Diagnosis	611.72
	ICD-10 Diagnosis	N63.xx
Mastodynia pain in breast	ICD-9 Diagnosis	611.71
	ICD-10 Diagnosis	N64.4
Other signs and symptoms in breast Induration of breast Inversion of nipple Nipple discharge retraction of nipple	ICD-9 Diagnosis	611.79
	ICD-10 Diagnosis	N64.5x
Specified congenital anomalies of breast Accessory breast or nipple Congenital absent breast or nipple Supernumerary breast or nipple	ICD-9 Diagnosis	757.6
	ICD-10 Diagnosis	Q83.x
Codes to identify breast involvement		
Secondary and unspecified malignant neoplasm of lymph nodes of axilla and upper limb Brachial Epitrochlear Infraclavicular Pectoral	ICD-9 Diagnosis	196.3
	ICD-10 Diagnosis	C77.3
Benign neoplasm of breast (female) connective tissue glandular tissue soft parts	ICD-9 Diagnosis	217.x
	ICD-10 Diagnosis	D24.x
Benign mammary dysplasia	ICD-9 Diagnosis	610.x
	ICD-10 Diagnosis	N60.x

Description	Code Type	Code
Inflammatory disease of breast	ICD-9 Diagnosis	611.0
	ICD-10 Diagnosis	N61.x
Hypertrophy of breast	ICD-9 Diagnosis	611.1
	ICD-10 Diagnosis	N62
Fissure of nipple	ICD-9 Diagnosis	611.2
	ICD-10 Diagnosis	N64.0
Fat necrosis of breast	ICD-9 Diagnosis	611.3
	ICD-10 Diagnosis	N64.1
Atrophy of breast	ICD-9 Diagnosis	611.4
	ICD-10 Diagnosis	N64.2
Galactocele	ICD-9 Diagnosis	611.5
	ICD-10 Diagnosis	N64.89
Galactorrhea not associated with childbirth	ICD-9 Diagnosis	611.6
	ICD-10 Diagnosis	N64.3
Other specified disorders of breast	ICD-9 Diagnosis	611.8x
	ICD-10 Diagnosis	N64.8x
Unspecified breast disorder	ICD-9 Diagnosis	611.9
	ICD-10 Diagnosis	N64.9
Nonspecific abnormal findings on radiological and other examination of breast - Includes: nonspecific abnormal findings of thermography ultrasound examination [echogram] x-ray examination	ICD-9 Diagnosis	793.8x
	ICD-10 Diagnosis	R92.8x
Family history of malignant neoplasm of breast	ICD-9 Diagnosis	V16.3
	ICD-10 Diagnosis	Z80.3
Codes to identify bilateral or unilateral mastectomy		
Bilateral simple mastectomy, Bilateral complete mastectomy	ICD-9 Procedure	85.42
	ICD-10 Procedure	0HTV0ZZ
Bilateral extended simple mastectomy	ICD-9 Procedure	85.44
	ICD-10 Procedure	0HTV0ZZ
Bilateral radical mastectomy	ICD-9 Procedure	85.46
	ICD-10 Procedure	0HTV0ZZ
Bilateral extended radical mastectomy	ICD-9 Procedure	85.48
	ICD-10 Procedure	0HTV0ZZ
Unilateral simple mastectomy, Mastectomy: NOS complete	ICD-9 Procedure	85.41
	ICD-10 Procedure	0HTT0ZZ 0HTU0ZZ
Unilateral extended simple mastectomy, Extended simple mastectomy NOS, Modified radical mastectomy, Simple mastectomy with excision of regional lymph nodes	ICD-9 Procedure	85.43
	ICD-10 Procedure	0HTU0ZZ 0HTU0ZZ
Unilateral radical mastectomy, Excision of breast, pectoral muscles, and regional lymph nodes [axillary, clavicular, supraclavicular], Radical mastectomy NOS	ICD-9 Procedure	85.45
	ICD-10 Procedure	0HTU0ZZ 0HTU0ZZ

Description	Code Type	Code
Unilateral extended radical mastectomy, Excision of breast, muscles, and lymph nodes [axillary, clavicular, supraclavicular, internal mammary, and mediastinal], Extended radical mastectomy NOS	ICD-9 Procedure	85.47
	ICD-10 Procedure	0HTU0ZZ 0HTU0ZZ
Mastectomy, simple, complete	CPT Procedure	19303
Mastectomy, subcutaneous	CPT Procedure	19304
Mastectomy, radical, including pectoral muscles, axillary lymph nodes	CPT Procedure	19305
Mastectomy, radical, including pectoral muscles, axillary and internal mammary lymph nodes (Urban type operation)	CPT Procedure	19306
Mastectomy, modified radical, including axillary lymph nodes, with or without pectoralis minor muscle, but excluding pectoralis major muscle	CPT Procedure	19307

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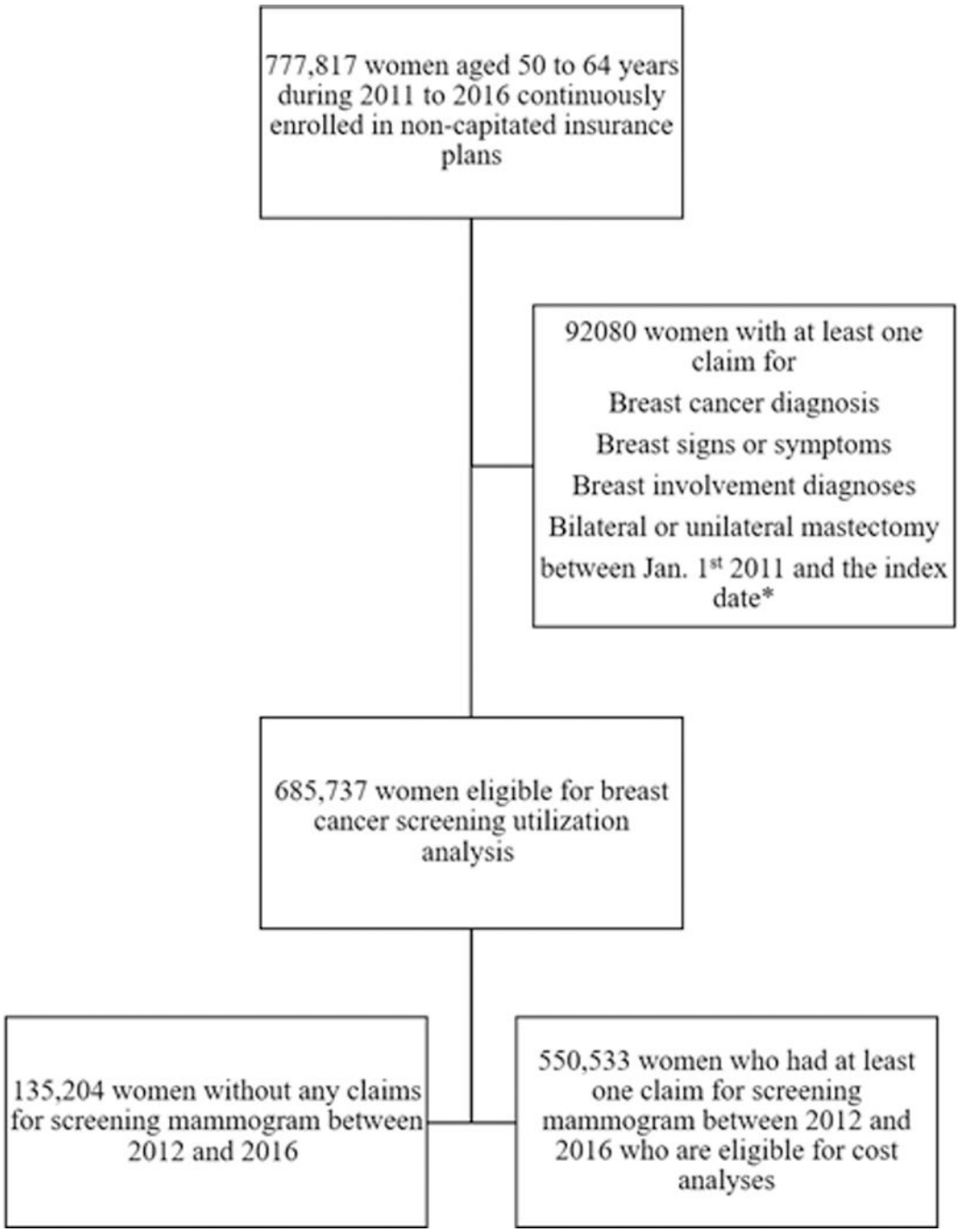

Figure 1.
Flow Diagram for Sample Selection

Table 1:

Demographic characteristics of study population, MarketScan, 2012–2016

Variable	Percent distribution (N=685,737)
Age in years	
50 to 54	37.39
55 to 59	51.46
60 to 64	11.15
Relationship to employer	
Spouse of employee	38.73
Employee	61.21
Region	
Northeast	17.15
Midwest	23.02
South	43.01
West	14.72
Metropolitan statistical area	
Yes	83.66
No	16.29
Insurance type	
Fee-for-service plan	7.53
Managed care-noncapitated plan	81.11
CDHP/HDHP[#]	11.36

#CDHP/HDHP: Consumer directed health plan/High deductible health plan

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Table 2:

Demographic characteristics of study population stratified by receipt and frequency of screening, MarketScan, 2012–2016

Variable	Percent received no screening (N=135,204)	Percent received at least one screening* (N=550,533)	Percent received annual screening* (N=273,949)	Percent received biennial screening* (N=166,579)	Percent received infrequent screening (N=110,005)
Age in years					
50 to 54	22.40	77.60	42.73	24.50	10.38
55 to 59	19.95	80.05	40.43	23.80	15.81
60 to 64	9.64	90.36	28.42	25.85	36.09
Relationship to employer					
Spouse of employee	22.05	77.95	36.87	24.05	17.02
Employee	18.21	81.79	41.92	24.45	15.42
Region					
Northeast	28.29	71.71	34.63	21.43	15.64
Midwest	19.62	80.38	39.61	24.28	16.48
South	17.51	82.49	42.31	24.30	15.88
West	17.30	82.70	38.49	27.42	16.79
Metropolitan statistical area					
Yes	19.48	80.52	40.05	24.41	16.06
No	20.91	79.09	39.46	23.69	15.94
Insurance type					
Fee-for-service plan	30.03	69.97	29.56	21.96	18.45
Managed care-noncapitated plan	19.48	80.52	40.21	24.33	15.99
CDHP/HDHP#	14.60	85.40	44.97	25.60	14.84

For bivariate analysis, those who received at least one screening were compared to those who received no screening. Those who received annual, biennial, and infrequent screening were compared to those who received no screening.

*All variable in the bivariate analyses were significant at p-value<0.01

#CDHP/HDHP: Consumer directed health plan/High deductible health plan

Table 3.

Multivariate logistic and multinomial logistic regression results for receipt of any screening and screening frequency, MarketScan, 2012–2016

Variable	Odds ratio (95% CI) for receiving at least one screening mammogram from 2012–2016 from logistic regression	Relative risk ratio (95% CI) for receiving annual screening from multinomial logistic regression	Relative risk ratio (95% CI) for receiving biennial screening from multinomial logistic regression	Relative risk ratio (95% CI) for infrequent screening from multinomial logistic regression
Age in years				
50 to 54	0.33 (0.32–0.34)*	0.62 (0.60–0.64)*	0.39 (0.38–0.40)*	0.12 (0.12–0.12)*
55 to 59	0.40 (0.39–0.41)*	0.67 (0.66–0.69)*	0.44 (0.43–0.45)*	0.21 (0.20–0.22)*
60 to 64 (Reference)	1.00	1.00	1.00	1.00
Relationship to employer				
Spouse of employee	0.87 (0.86–0.88)*	0.82 (0.81–0.83)*	0.91 (0.89–0.92)*	1.01 (1.00–1.03)
Employee (Reference)	1.00	1.00	1.00	1.00
Region				
Northeast	0.59 (0.58–0.60)*	0.50 (0.50–0.51)*	0.54 (0.53–0.55)*	0.61 (0.60–0.63)*
Midwest	0.88 (0.86–0.89)*	0.94 (0.92–0.95)*	0.97 (0.95–0.99)*	0.97 (0.95–0.99)*
West	1.07 (1.05–1.09)*	0.89 (0.87–0.91)*	1.10 (1.09–1.13)*	1.07 (1.04–1.10) *NS*
South (Reference)	1.00	1.00	1.00	1.00
Metropolitan Statistical Area				
Yes	1.30 (1.28–1.32)*	1.19 (1.17–1.21) *NS*	1.18 (1.16–1.21) *NS*	1.15 (1.13–1.18)*
No (Reference)	1.00	1.00	1.00	1.00
Insurance type				
Managed care-noncapitated plan	1.98 (1.94–2.03)*	2.17 (2.11–2.22)*	1.82 (1.77–1.87)*	1.63 (1.58–1.68)*
CDHP/HDHP#	2.68 (2.60–2.76)*	3.05 (2.96–3.15)*	2.47 (2.39–2.56)*	2.00 (0.79–0.84)*
Fee-for-service plan (Reference)	1.00	1.00	1.00	1.00

No screening is the referent group for the multinomial logistic regression

*Significant at p-value<0.01;

*NS*Not Significant at p-value<0.05

#CDHP/HDHP: Consumer directed health plan/High deductible health plan

Table 4.

Receipt and cost of screening modalities by type of insurance, MarketScan, 2012–2016

	Women who received screening modality (%) (95% CI)	Mean Direct Medical Cost* (2017 $) (95% CI)	Women with some OOP cost (%) (95% CI)	Mean OOP cost* (2017 $) (95% CI)
Film mammogram				
Fee-for-service plan	25.57 (25.12–26.02)	129.44 (127.44–131.45)	0.40 (0.27–0.53)	73.16 (35.85–110.48)
Managed care-noncapitated plan	18.45 (18.33–18.56)	113.06 (112.16–113.95)	4.04 (3.91–4.18)	47.97 (44.27–51.77)
CDHP/HDHP	24.93 (24.60–25.26)	98.40 (96.11–100.69)	0.77 (0.64–0.91)	67.54 (43.31–91.78)
Overall	19.70 (19.59–19.80)	112.75 (111.97–113.54)	3.23 (3.13–3.34)	48.76 (45.01–52.41)
Digital mammogram				
Fee-for-service plan	96.34 (96.18–96.56)	180.79 (179.37–182.21)	0.51 (0.43–0.58)	69.79 (53.14–86.46)
Managed care-noncapitated plan	97.67 (97.63–97.72)	177.394 (176.96–177.82)	4.15 (4.09–4.21)	61.89 (60.25–63.54)
CDHP/HDHP	97.75 (97.63–97.86)	159.88 (158.63–161.13)	0.82 (0.75–0.89)	88.10 (73.66–102.53)
Overall	97.60 (97.56–97.64)	175.58 (175.18–175.97)	3.51 (3.46–3.56)	62.66 (61.01–64.31)
CAD				
Fee-for-service plan	95.97 (95.76–96.17)	25.51 (25.20–25.81)	1.75(1.61–1.89)	8.06 (6.92–9.20)
Managed care-noncapitated plan	96.38 (96.33–96.44)	26.03 (25.91–26.16)	3.41 (3.35–3.46)	10.69 (10.12–11.27)
CDHP/HDHP	95.91 (95.76–96.06)	42.33 (41.55–43.11)	0.78 (0.71–0.85)	30.78 (18.65–42.90)
Overall	96.30 (96.25–96.35)	28.42 (28.27–28.57)	2.98 (2.94–3.03)	10.79 (10.10–11.48)
DBT				
Fee-for-service plan	11.51 (11.18–11.84)	10.97 (9.69–12.26)	6.50 (5.75–7.25)	22.70 (18.71–26.68)
Managed care-noncapitated plan	13.88 (13.78–13.99)	33.90 (33.30–34.15)	8.09 (7.87–8.30)	39.98 (38.10–41.86)
CDHP/HDHP	16.09 (15.81–16.37)	28.15 (26.54–29.77)	6.63 (6.16–7.11)	51.26 (45.68–56.85)
Overall	13.99 (13.90–14.09)	31.83 (31.29–32.37)	7.80 (7.61–7.99)	40.52 (38.79–42.24)
Total			5.17 (5.11–5.23)	

*The mean direct medical cost are presented only for those who reported receiving that screening modality and OOP costs are presented only for those women who had any OOP costs

#CAD: Computer aided detection; DBT: Digital breast tomosynthesis; CDHP/HDHP: Consumer directed health plan/High deductible health plan; OOP: Out of pocket

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Table 5:

Total number of screens and mean costs for screening by screening frequency, MarketScan 2012–2016

Breast Cancer Screening Frequency	Mean total cost for all screens/ person from 2012–2016 (2017$) (95% CI)	Aggregate cost for sample* (million $) (95% CI)
Annual screening (N=273,949)	1411.23 (1407.35–1415.1)	38.66 (38.55–38.77)
Biennial screening (N=166,579)	792.10 (789.13–795.07)	13.19 (13.15–13.24)
Infrequent screening (N=110,005)_	310.93 (309.30–312.56)	3.42 (3.40–3.44)
Total (N=550,533)	1003.88 (1001.38–1006.38)	55.27 (55.13–55.40))

*Computed as Average total cost per person*N